

Large all-Metal Dual-Frequency Circularly Polarized High Gain Antenna for potential Europa Lander

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Abstract—A new all-metal dual-frequency RHCP high gain antenna is under development at NASA's Jet Propulsion Laboratory for a potential Europa Lander. The antenna is mainly made of metal so it could survive the harsh environment conditions (i.e. very low temperature and high radiation and ESD levels). The antenna is also flat to meet drastic volume constraints and has efficiencies higher than 80% at both the uplink and downlink X-band Deep Space frequency bands. This antenna is a key component for the potential mission enabling Direct Link to Earth (DTE) from and Direct-from-Earth (DFE) to the lander without any relay.

Index Terms—antenna, array, stripline, waveguide, dual frequency, DTE, DFE, telecommunication, patch.

I. INTRODUCTION

Europa Lander is a proposed NASA astrobiology concept mission that would place a lander on Europa, a moon of Jupiter which is thought to have a liquid ocean under its icy surface as well as water plumes. If selected and developed, the Europa Lander would be launched in 2025 to complement the science undertaken by the Europa Clipper mission. The objectives of the Europa Lander would be to search for biosignatures at the subsurface, to characterize the composition of non-ice near-subsurface material, and determine the proximity of liquid water and recently erupted material near the lander's location [1].

For telecommunication, the Europa Lander Project is exploring the possibility of relying solely on communication with Earth, Direct-to-Earth (DTE) and Direct-from-Earth (DFE) rather than relaying signals via a nearby spacecraft. This would require a large antenna aperture and a high transmitter power of at least 100W. The antenna must operate well at both the uplink (7.145-7.190 GHz) and downlink (8.40-8.45GHz) Deep Space frequency bands and must handle up to 100 W of input power in a vacuum.

The European environment presents extreme challenges due to its high radiation and ESD levels and ultra-low temperatures. In addition to these severe environment conditions, there are tight volume constraints forcing the antenna to be completely flat and limiting its size. To withstand the harsh temperature conditions and radiation levels, the antenna should be made mainly of metal.

The maximum aperture area that would be available is $82.5\text{cm} \times 82.5\text{cm}$ and therefore, very high efficiency (>80%) is required to close the link from Europa. Several antennas, such as RLSA [2] or metasurface antennas [3],[4], were initially considered but found not to meet the high efficiency requirements at both frequencies.

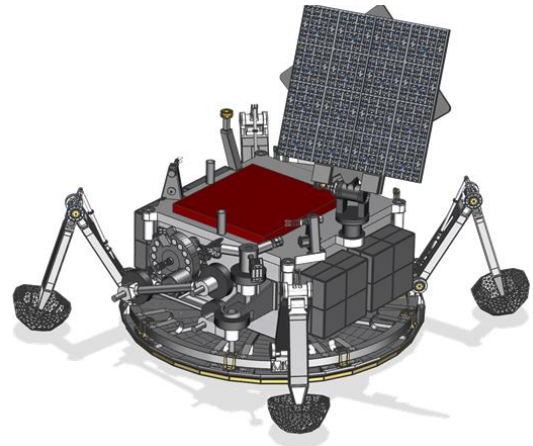


Fig. 1. An artist's concept of a potential Europa Lander with the all-metal dual-frequency RHCP HGA for DTE / DFE.

Researchers have investigated different approaches to obtain dual-band or wideband performance in CP patch antennas, including stacked patch antennas, slotted patch shapes, slotted ground planes, E-shaped, U-slot, L-shaped, and so on. None of the aforementioned solutions is compatible with all-metal solutions that could potentially scaled to a very large array.

NASA's Jet Propulsion Laboratory is developing a new type of all-metal RHCP patch array with the potential of demonstrating more than 80% efficiency at both uplink and downlink frequencies [5]. The dual-frequency RHCP antenna will leverage construction methods developed for the Juno MicroWave Radiometer single-frequency linearly polarized patch array antennas [6]. We strongly believe that the proposed all metal dual-band RHCP high gain antenna will pave the way for the next generation of Deep Space DTE/DFE antennas enabling revolutionary new concepts for space exploration in harsh environments.

II. ANTENNA DESCRIPTION

The DTE antenna consists of 32×32 patch array as illustrated in Fig. 1. The 32×32 patch array is composed of four panels. Each panel is made up of four subarrays. Each of the 8×8 patch subarray elements are fed using air stripline which is housed under the top ground plane. Each subarray is fed using WR-112 waveguides beneath the antenna. Using waveguides to feed all 16 subarrays allows the antenna to support high input or transmitter power levels. For an input power of 100W, the power seen at the stripline input would

be 6.25W. It also simplifies the matching network. A WR-112 waveguide to air-stripline transition was designed specifically for this antenna. The spacing between each patch element is $0.62 \cdot \lambda_0$ and was chosen to fit the antenna in the allocated volume. This simple, building block, antenna architecture compartmentalizes the design challenges that must be addressed and allows the designers to reuse solutions as needed. A gain of more than 36.0dBi and 37.1dBi is reached at uplink and downlink frequency bands, respectively.

The subarray is an 8×8 patch array fed using an air stripline feed network. The air stripline is very low loss. The thickness was chosen to have sufficient margin against multipaction (i.e. more than 20dB).

We have successfully fabricated and test a 16×16 patch array and we are in the process of building a 32×32 patch array. This is to the best of our knowledge the first all-metal patch array combining air strip line and waveguides to achieve very high efficiency and high power handling for deep space communication. The 32×32 patch array is under fabrication. The measurement results will be presented during the conference. We are expecting to maintain 80% efficiency at both uplink and downlink frequency bands.

III. CONCLUSION

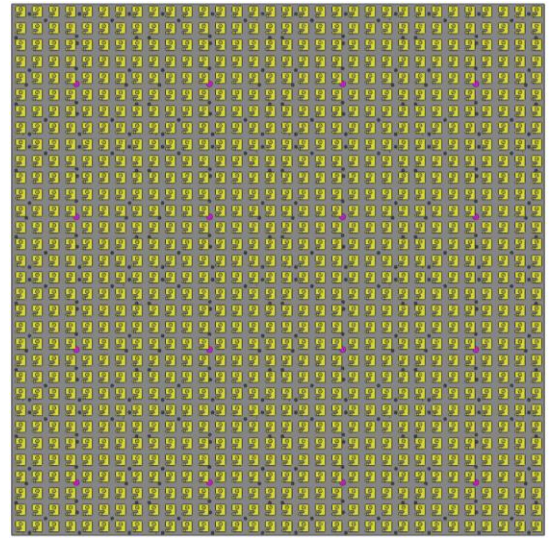
The high gain antenna for a potential Europa Lander is described. It consists of 16 sets of 8×8 patch subarrays. Low-loss air striplines are employed to feed the 8×8 patch elements within each subarrays. Each subarrays are fed using a 1-to-16 waveguide power divider.

The antenna can easily sustain the input power of 100W in vacuum and it was designed to survive the harsh environment of Europa (i.e. high radiation and ESD levels and low temperatures).

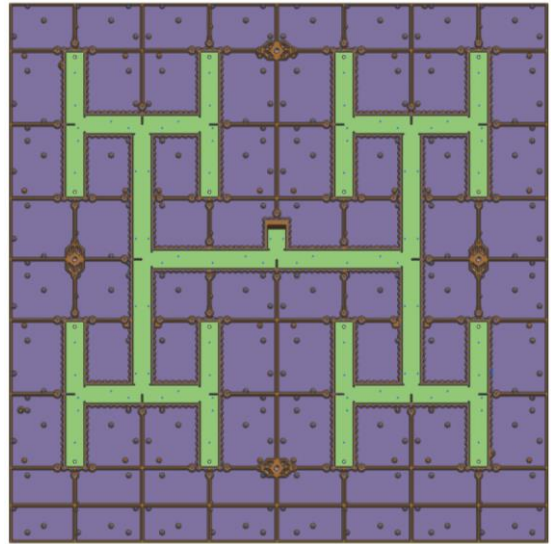
We are currently assembling the 32×32 patch array to qualify it for the potential Europa Lander mission with the objective of reaching test readiness level of 6. The results will be presented during the conference.

ACKNOWLEDGMENT

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(a)



(b)

Fig. 2. (a) Front and (b) back view of 32×32 patch fed with waveguides and air strip lines.

REFERENCES

- [1] NASA/JPL, "Europa Lander study 2016 report, Europa Lander Mission", JPL D-97667, Feb. 2017.
- [2] M. Bray, "A radial line slot array antenna for deep space missions," 2017 IEEE Aerospace Conference, Big Sky, MT, 2017.
- [3] D. González-Ovejero, G. Minatti, G. Chattopadhyay and S. Maci, "Multibeam by metasurface antennas," *IEEE Trans. Antennas Propag.*, vol. 65, no. 6, pp. 2923-2930, Jun. 2017.
- [4] D. González-Ovejero, N. Chahat, R. Sauleau, G. Chattopadhyay, S. Maci and M. Ettore, "Additive Manufactured Metal-Only Modulated Metasurface Antennas," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 11, pp. 6106-6114, Nov. 2018.
- [5] N. Chahat, B. Cook, H. Lim and P. Estabrook, "All-Metal Dual-Frequency RHCP High-Gain Antenna for a Potential Europa Lander," *IEEE Transactions on Antennas and Propagation*, vol. 66, no. 12, pp. 6791-6798, Dec. 2018.
- [6] N. Chamberlain, J. Chen, P. Focardi, R. Hodges, R. Hughes, J. Jakoboski, J. Venkatesan, M. Zawadzki, "Juno Microwave Radiometer Patch Array Antennas," *IEEE Antennas and Propagation Society International Symposium, APSURSI09*, 2009.